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# How does accessibility to post-disaster relief compare between the aging and the general population? A spatial network optimization analysis of hurricane relief facility locations

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ABSTRACT

When maximizing the effectiveness and equity in hurricane disaster relief provision, most research has explored the needs of various socioeconomic groups. Besides income, the age of the population can also be an important metric of equity, as evidenced by the disproportionate death toll in New Orleans' aging population caused by Hurricane Katrina. Yet emergency management and transportation research has not given sufficient consideration to the impacts of age-based demand on the provision of disaster relief. This paper looks at relief distribution to non-evacuating populations in a post-disaster disaster setting to compare the accessibility to relief of the aging vs. other populations. A *p*-median based modeling framework linked to a geographic information system (GIS) is employed to explore the influence of the age of potential hurricane non-evacuees on the decision of where to site relief distribution facilities in Leon County, Florida. It was found that the average travel time between neighborhoods and sited nearest facilities varies as a function of demand specifications with the *Population age 65 and over* tending to bear a relatively higher burden of the travel time, which may limit their accessibility to post-disaster relief in comparison with the Total Population as well as those aged under 65. Changing how relief demand is represented (in terms of age) results in changes to the sited relief facilities' spatial layouts. Our results suggest the need for emergency planners to consider aging populations and their disaster-related needs into future planning efforts to ensure a more equitable disaster relief distribution system.



## 1. Introduction

Countries of the developed world are aging at a fast pace and are threatened by an unprecedented occurrence of disasters which have increased 14-fold since the 1950s [1,2]. In the US, the combination of a growing population coupled with development in coastal zones, rising ocean levels, coastal erosion, and changing climatic trends have increased vulnerability to hurricanes [3,4]. Out of the 284 hurricanes having affected the US between 1851 and 2010, 114 (including 37 major and 3 of the 4 US costliest hurricanes (e.g. Katrina, Andrew, and Wilma) directly hit Florida [5], making it the most hurricane-prone state of the US. With 23.6% of its residents aged 60 or more [6], Florida leads the U.S. in terms of its aging proportion of the total population [7]. In that state where proportions of older adults are expected to increase substantially [8], efficient and effective management of aging people's disaster needs becomes an important management issue. Particularly crucial in post-event settings, such needs relate mainly to transportation, healthcare access, and aid distribution among others [9].

Disasters seem to disproportionately affect some demographic groups [including older adults] [10,11]. Research shows that older adults are more vulnerable to the impacts of disasters as compared with other age groups [11–16]. The higher death toll (1330 deaths: 71% of the casualties) claimed by Hurricane Katrina in New Orleans, LA among adults aged 60+ despite them making just 15% of the local population [13] illustrates the challenge. This is because older adults may be affected by impaired health conditions, disabilities and social and economic restraints [14,17–19] which render them more vulnerable. While immediate survival in an emergency often depends on rapid access to relief [20], older people may be the most disadvantaged when it comes to receiving disaster relief due to the distances involved, their poor mobility and the resulting difficulty of accessing centralized relief delivery points. With the potential for older people to be generally unable to evacuate and left behind in times of emergencies, relief goods and service delivery points should be made as accessible as

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possible to them [20].

Facility location decisions (defined in terms of the number and locations of relief distribution centers) can directly affect the performance of relief operations (measured as the response time and costs incurred throughout the supply chain) [21]. Strategic placement of relief distribution facilities is a prerequisite for efficient and effective logistics operations [22] which are either emergency-based/humanitarian or business-based/commercial in nature. Central to disaster relief, humanitarian logistics is the process of planning, implementing and managing the efficient, cost-effective flow and storage of goods and materials, as well as related information, from the points of origin to the points of consumption for the purpose of aiding affected people [23]. 'Humanitarian logistics' is a term covering several activities occurring at multiple phases of emergency management (e.g. planning, response, recovery, and preparedness including the pre-positioning of relief goods) [24]. Unlike commercial logistics which is pursuant to economic activity, humanitarian logistics aims to alleviate the suffering of vulnerable people [22,23,26,27]. It focuses on user accessibility and response time [21] and remains a key part of alleviating disaster impacts in the immediate aftermath [25]. Estimation of the post-disaster demand for relief is an important avenue for research [26] and aid distribution is a key aspect of emergency response that can be enhanced to address [post-disaster] needs of aging populations [9].

Some post-disaster goods distribution research has focused on serving the potentially worst-off people in an attempt to address disparities associated with relief distribution. Research [28,29] has tackled such equity issues through highlighting the potentially reduced access to disaster relief of people with lower income due to their (suboptimal) locations relative to the relief facilities' placement. In the same way as income, the age of the population can be an important factor regarding equity in disaster relief access. However, emergency management and transportation scholarship has not given enough consideration to the impacts of age-based demand assumptions on the accessibility to disaster relief.

This research seeks to understand older adults' disaster vulnerability and to implement spatial optimization models that increase their access to relief resources. Specifically, the objectives of this research are to compare the service needs of the aging vs. general populations in terms of the strategic siting of disaster relief distribution centers. To this end, we conduct a case study in Leon County, FL; a smaller metropolitan area. We explore the influence of the age of potential disaster victims on the decision of where to site relief distribution facilities. We employed a *p*-median based spatial modeling framework linked to a geographic information system, (GIS) to explore the extent to which configurations of relief facilities adequately serve aging populations.

This effort builds on past research by focusing on the post-disaster distribution of emergency supplies (e.g. water, ice, food) pre-positioned in locations throughout Leon County, FL. In a real-world disaster, relief efforts are coordinated by local government agencies and institutions traditionally involved with relief provision (e.g. the American Red Cross). This research focuses specifically on the issue of basic commodity distribution relative to older adults who do not evacuate. Ideally such efforts would improve their accessibility and minimize suffering [30]. The chosen distribution architecture is related to existing governmental emergency planning guidelines and schematics (e.g. Florida Comprehensive Emergency Plan) specifying the roles and responsibilities of government agencies in pre-positioning emergency supplies in distribution facilities where disaster survivors may receive them. It is important to note however that the emphasis in this research is on the spatial modeling issues inherent to relief provision and not the roles of government and related actors. Accordingly, the models proposed herein minimize the average travel time separating neighborhoods to their nearest relief distribution facilities through spatially optimizing the placement of such facilities. Doing so, we endeavor to shed more light on emergency logistics needs for specific populations, a complex research field only partially elucidated so far [26,31].

## 2. Background

### 2.1. Defining older adults and their disaster vulnerability and needs

The ages of 60 or 65 years [9] are commonly accepted as a starting definition for aging people, and such older adults are also referred to as "seniors," and "aged", terms which are tied to a chronological age [32]. Natural waning of physical and cognitive abilities [20,32,33], chronic disease-related conditions, reduced sensory awareness, social and economic restraints [9,14,17,32], physical frailty, and social isolation [9,17] are all conditions that may affect older adults to put them at greater risk during extreme events. So that other terms including "frail elderly" and "fragile elderly" [also refer to older adults] to denote a health or mobility impairment in addition to advanced age [9,19,33].

'Social vulnerability' captures both the sensitivity of a population to natural hazards and its ability to respond to and recover from the impacts of hazards [34]. Along with race/ethnicity, socioeconomic class, and gender, age is an important characteristic defining vulnerable populations including the elderly. Aging populations are potentially more vulnerable to disasters because of issues ranging from physical limitations and declining cognitive abilities to process hazard information, to fewer economic resources to repair disaster damaged homes [34]. Most research highlights the differentially higher vulnerability of older adults to the impacts of disasters as compared with other age groups [12–16]. The American Red Cross, the Center for Disease Control and Prevention and other related agencies recognize the elderly individuals as a critical age group since they have disproportionate vulnerability with respect to immediate and future effects of disasters on them [35]. This suggests the need for emergency planners to account for this vulnerability [1]. It is particularly important to successfully manage older adults' vulnerability in Florida, a disaster-prone state which, additionally, has a large aging population [7]. Rather than age alone, it is the correlation between advancing age and the likelihood of having medical special needs that increases one's frailty and makes a person more vulnerable [9]. Considering [all] older adults as a 'disaster vulnerable' population is not always appropriate [36]. There are those among the aging population that are relatively healthy and live independently, and whose age would not impede them from acting on disaster information [37]. While others would need substantial support to do so, some older adults are able to take protective actions to evade disasters' impact [32]. Based on a lifetime of experiences, older adults might even bring elements of strength and resilience to the disaster [management] experience [36]. Nevertheless, even healthy older people can be at increased risk and require assistance in a disaster [38]. With approximately 80% of them having one chronic condition [39], and 37% reporting a disability that impacts their activities of daily living, ADLs [8,40], U. S. seniors, more than likely, are vulnerable to disasters and have special needs that emergency management should recognize [9].

A scan of the literature suggests that disaster management efforts have not given adequate attention to the particular needs of older people. As vulnerability and potential needs of the elderly are still not yet well understood [1], emergency managers and local agencies dedicated to their well-being must ensure that [post-disaster] services provided to the elderly enable them to recover from a disaster [9].